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# **A Study to Determine Whether Cavitation Occurs around Dental Ultrasonic Scaling Instruments**

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**Abstract**

The aim of this investigation was to determine if cavitation occurred around dental ultrasonic scalers and to estimate the amount of cavitation occurring. Three styles of tip (3 x TFI-10, 3 x TFI-3, 3 x TFI-1) were used, in conjunction with a Cavitron SPS ultrasonic generator (Dentsply, USA), to insonate terephthalic acid solution. The hydroxyl radical, [ $\bullet\text{OH}$ ], concentration, produced due to cavitation from the scaler tips, was monitored by fluorescence spectroscopy. Cavitation activity was enhanced at higher power settings and at longer operating times. The tip dimensions and geometry as well as the generator power setting are both important factors that affect the production of cavitation.

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Keywords: Dental Ultrasonic Scaler, Cavitation, Terephthalate Dosimeter.

## Introduction

Ultrasonic scaling instruments, used in dentistry, operate at frequencies between 25 and 30 kHz. The primary cleaning action of these instruments is attributed to the vibratory motion of the scaler probe. However, another process that may aid in the removal of substances from tooth surfaces is the phenomenon of cavitation, which occurs in the cooling water as it flows over the insert probe [1].

When water is irradiated with ultrasound,  $\bullet\text{OH}$  and  $\text{H}\bullet$  radicals are formed (Scheme 1) due to the high energies generated during cavitational bubble collapse [2]. Cavitation occurring around dental ultrasonic instruments may be quantified by monitoring its chemical effects, using oxidation reactions such as in the Weissler reaction [3] or Fricke's dosimeter and also by direct detection of radical species. However, both the Weissler reaction and Fricke's dosimeter are susceptible to all oxidising species in solution, such as  $\text{HO}_2\bullet$  and  $\text{H}_2\text{O}_2$  [4].

The terephthalate dosimeter is a system that measures  $\bullet\text{OH}$  radical yield specifically [4,5]. The system uses an aqueous solution of terephthalic acid that on reaction with hydroxyl radicals forms 2-hydroxyterephthalate, HTA, (Scheme 2) [5] and is readily detectable using fluorescence spectroscopy [4,6].

The aim of this investigation was to determine if cavitation occurred around dental ultrasonic scalers and, if so, to estimate the amount of cavitation occurring, using the terephthalate dosimeter.

## Materials and Methods

A solution of terephthalic acid (TA) was prepared by dissolving, with heating, 0.3323g (0.002mol) in 1dm<sup>3</sup> deionised water containing 25cm<sup>3</sup> of pH 7.0 non-fluorescent buffer [4].

Three different styles of tip (3 x TFI-10, 3 x TFI-3, 3 x TFI-1) were used (Figure 1) in conjunction with a Cavitron SPS ultrasonic generator (Dentsply Preventive Care, York, PA, USA). During normal use, water flows through the handpiece of the scaler and over the length of the tip. Water was required throughout this investigation to regulate the handpiece temperature but could potentially interfere with the results by diluting the TA solution. A rubber dam was therefore placed over the tip to direct the cooling water away from the cuvette. The arrangement of the apparatus is shown in Figure 2.

A tip was inserted into a cuvette containing 3.5cm<sup>3</sup> of aqueous TA solution and operated at a low generator power setting for 1 minute. The tip was removed and the cuvette was placed in a fluorescence spectrometer (Perkin Elmer 3000) using an excitation wavelength of 325nm while monitoring the fluorescence emission at 425nm. The procedure was repeated 5 times using fresh solution to enable a mean [ $\bullet$ OH] concentration to be calculated (Table 1). Measurements were repeated for sonication times of 2 and 5 minutes. The power of the generator was then increased, successively, to medium and high power and 5 repeat measurements performed for 2 and 5 minutes sonication.

This process was repeated for each tip design at low, medium and high generator power settings. The increase in fluorescence is proportional to the concentration of [ $\bullet$ OH] produced. In order to relate the fluorescence emission to the actual concentration, the response of the spectrometer was determined by calibration with a synthesised sample of HTA [5].

Prior to each measurement, the spectrometer was zeroed using a cuvette of unsonicated TA solution.

## Results

Any cavitation that might have been produced by the TFI-1 tips was below the limit of detection ( $< 10^{-8}$  M) at all powers. Likewise, any cavitation produced by the TFI-3 or TFI-10 scaler tips at low generator power setting for up to 5 minutes sonication was also below the limit of detection ( $< 10^{-8}$  M). No cavitation was detected at medium power for the TFI-10 tips (2 & 5 minutes) except for tip 2, which showed very small  $\bullet\text{OH}$  radical concentrations (Table 1). All TFI-10 tips produced cavitation at the high power setting (Table 1). All TFI-3 tips produced cavitation at both medium and high power settings (Table 1).

Using multiple post-hoc comparisons (Tukey test, general linear model, analysis of variance) at a significance level of  $p < 0.05$  and with the dependent variable being the  $[\bullet\text{OH}]$  concentration, a significant difference was found between all TFI-3 scaler tips at all power settings ( $p < 0.0001$ ). No significant difference was found between any of the TFI-10 scaler tips ( $p > 0.43$ ).

## Discussion

This work has demonstrated that chemical reactions resulting from cavitation activity do occur around dental ultrasonic scaler tips under certain operating conditions and is in agreement with previous work [3]. Tip shape and generator power setting were both shown to have an effect on radical production.

The geometry of the scaler tips affects the magnitude of their vibration displacement amplitude. The TFI-10 and TFI-3 style scaler tips have greater vibration displacement amplitudes, at a given power setting, than the TFI-1 scaler tip and this is reflected in the results obtained in this study.

The TFI-10 style tips produced cavitation (that could be detected) at the high generator power setting and the TFI-3 style tips produced cavitation at both medium and high generator powers. The TFI-1 tips produced no detectable cavitation at any generator power setting.

Sonication time was also shown to affect cavitation production (Figures 3 and 4). For the TFI-10 and TFI-3 tips, [ $\bullet$ OH] production increased with time. Regression analysis of the data showed that this increase was linear, with  $R^2$  values of between 0.97 and 1. However, although hydroxyl radical production increased with increasing sonication time the rate of radical production was approximately the same for each sonication period.

Variation in the amount of cavitation detected was also shown to occur between tips of the same style. The amount of cavitation produced / detected around TFI-3 tip 2 was less than that detected around the other two tips and statistical analysis demonstrated that in fact all three tips were significantly different to each other. TFI-10 tip 2 produced cavitation at the medium power setting, whereas tips 1 and 3 did not. Although no significant differences were observed between any of the TFI-10 tips statistically, tips 1 and 3 were more similar to each other ( $p>0.97$ ) than they were to tip 2 ( $p>0.43$ ).

This variation in the amount of cavitation produced / detected, between tips of the same design (for given generator power setting / sonication time), is likely to be due to the variation in the vibration displacement amplitude of the tips that has been shown to occur [7-9]. Differences in the amount of cavitation generated between tips of different styles may be due to the differences in the surface areas of the tip surfaces transmitting the ultrasound into the TA solution.

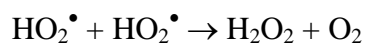
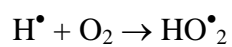
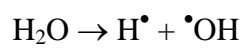
Following experimentation, the TFI-3 scaler tips were observed to have regions of increased wear on their surfaces (Figure 5). It is thought that these regions correspond to positions on the scaler tip of high cavitation activity and this warrants further investigation.

## **Conclusions**

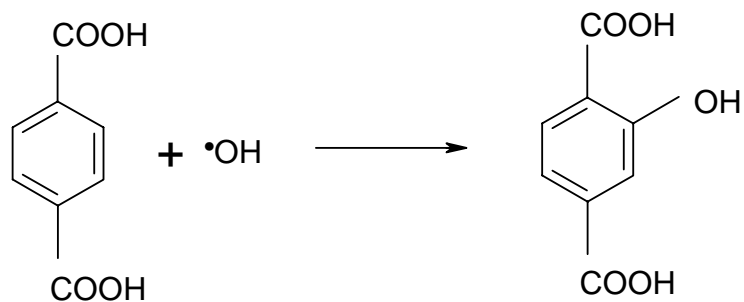
This investigation has demonstrated that under certain operational conditions cavitation occurred around dental ultrasonic scalers. The terephthalate dosimeter method was effective in measuring hydroxyl radical concentration produced due to cavitation from scaler tips. Increased cavitation activity occurred at higher power settings and with increased operating time. The TFI-3 tip working at high power resulted in most cavitation activity. The dimensions of the tip and the generator power setting are both important factors that affect the production of cavitation.

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Scheme 1. Radical production due to water sonication



Scheme 2. Mechanism for the formation of hydroxyterephthalate.

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## Figure Legends

- Figure 1. Scaler tips used in this study including (L-R): TFI-1, TFI-3 and TFI-10.
- Figure 2. Arrangement of the scaler tip and cuvette as used during experimentation. Rubber dam was used to prevent water, flowing through the scaler handpiece, reaching the tip.
- Figure 3. Graph demonstrating the effect of sonication time on  $\bullet\text{OH}$  radical production for TFI-10 tips.
- Figure 4. Graph demonstrating the effect of sonication time on  $\bullet\text{OH}$  radical production for TFI-3 tips.
- Figure 5. TFI-3 scaler tips before (left) and following (right) sonication. The tip on the right has regions of increased wear at both the end and the bend of the instrument and these may be regions of increased cavitation activity.

Tip design (# number) / generator power	[•OH] concentration (x 10 <sup>-6</sup> M)		
	1 minute sonication	2 minute sonication	5 minute sonication
All <b>TFI-1</b> Tips / All Powers	NDC	NDC	NDC
All <b>TFI-10</b> / <b>TFI-3</b> Tips / Low Power	NDC	NDC	NDC
<b>TFI-10</b>			
#1 Medium Power	NDC	NDC	NDC
#1 High Power	0.35 ± 0.01	0.53 ± 0.05	1.47 ± 0.13
#2 Medium Power	NDC	0.06 ± 0.03	0.09 ± 0.03
#2 High Power	0.34 ± 0.02	0.57 ± 0.03	1.22 ± 0.05
#3 Medium Power	NDC	NDC	NDC
#3 High Power	0.40 ± 0.03	0.61 ± 0.04	1.33 ± 0.06
<b>TFI-3</b>			
#1 Medium Power	0.30 ± 0.01	0.54 ± 0.03	1.38 ± 0.03
#1 High Power	0.47 ± 0.04	1.06 ± 0.03	1.87 ± 0.08
#2 Medium Power	0.12 ± 0.03	0.20 ± 0.01	0.50 ± 0.04
#2 High Power	0.30 ± 0.02	0.57 ± 0.05	1.25 ± 0.06
#3 Medium Power	0.26 ± 0.01	0.48 ± 0.03	1.13 ± 0.01
#3 High Power	0.54 ± 0.03	0.83 ± 0.05	1.62 ± 0.16

Table 1. [•OH] concentrations obtained following sonication of terephthalic acid solution, (NDC = no detectable cavitation).

